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THE LARVAL HABITATS AND REARING OF SOME COMMON *CHRYSOPS* SPECIES (DIPTERA: TABANIDAE) IN NEW HAMPSHIRE[1]

J. F. Burger, D. J. Lake, and M. L. McKay

Department of Entomology, University of New Hampshire, Durham, New Hampshire 03824.

Abstract.—Approximately 1230 larvae and pupae of ten early season *Chrysops* species were collected and reared over three years, with *Chrysops mitis* Osten Sacken (500), *C. ater* Macquart (225) and *C. indus* Osten Sacken (124) most commonly collected. The most consistently favorable collecting sites were natural or artificial ponds; the least favorable sites were rocky bottomed streams. Permanent ponds with exposed loamy soils just above waterline consistently supported large numbers of common *Chrysops* species. Factors affecting collecting and rearing success include synchronization of prepupal and pupal stages and adult emergence, yearly variation in pupation and emergence time, amount and quality of lacustrine substrate available for pupation, seasonal succession of species cohorts or different species in the same habitat, and abundance of a parasitoid wasp, *Diglochis occidentalis* (Ashmead) (Pteromalidae), in pupae. Yearly variation in amount of favorable pupation substrate most directly affected collecting success in a particular habitat, while percent parasitism by *D. occidentalis* most directly affected rearing success in the laboratory. A brief discussion of *Chrysops* larval habitat types in North America is presented, with a summary of larval habitats for 55 Nearctic species.

In 1977–79, *Chrysops* larvae were collected from several lacustrine habitats in New Hampshire to be reared for studies on adult alimentary canal morphology and ovarian development. Several habitats examined yielded large numbers of some *Chrysops* species. Since the habitats of these species were not the same as those described by Teskey (1969), they were studied to determine what species occur there, whether species composition differs from year to year, to what extent numbers of each species differ from year

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to year, to document pupation and adult emergence times, and to develop collection and rearing techniques for laboratory studies. Because the *Chrysops* species studied congregate in favorable substrates, pupate, and emerge synchronously and do not seem to be cannibalistic, they can be used for ovarian development and autogeny studies (Lake and Burger, 1980). The data presented represent a summary of observations for three years at two sites, two years at two sites, and one year at six sites in western and northern New Hampshire.

Summary of Known Larval Habitats of *Chrysops* Species in North America

Deer flies most frequently deposit their eggs in masses on emergent or overhanging vegetation in or near lakes, ponds, ditches, swamps, bogs, and streams. Larvae probably occur in soil beneath water during all but the prepupal stage. Prior to pupation, larvae tend to move above the waterline and may congregate in favorable drier substrates. A mature larva orients itself head up 1–5 cm below the soil surface and pupation occurs in this position. Adult flies emerge 7–14 days following pupation.

During the last 60 years, the larvae and/or larval habitats of about 60 of 85 Nearctic *Chrysops* species have been described, beginning with Marchand (1917, 1920), who emphasized egg laying habits of female *Chrysops* and briefly described the larvae of two species. Cameron (1926) discussed six species in Canada. Other early papers by Stone (1930) and Philip (1931) added twelve more species. Jones and Anthony (1964), Hays and Tidwell (1967), Goodwin (1972), and Tidwell (1973) described the habitats of some *Chrysops* species found in the southeastern United States. Teskey (1969) described the larval habitats of 36 *Chrysops* species from the eastern United States and Canada and provided a comprehensive treatment of their taxonomy and biology. Teskey and Burger (1976) described the immature stages of another species, *Chrysops sequax* Williston. In the western United States, Gjullen and Mote (1945) discussed the larval habitat of *Chrysops discalis* Williston in Utah, Lane (1975) described habitats of six species in California, and Burger (1977) described the larval habitats of three species occurring in Arizona.

Of the 60 *Chrysops* species whose larval stages are known, only 55 have a sufficiently detailed description of the larval habitat to allow comparison with other species. The greatest diversity of *Chrysops* species occurs only or predominantly in lentic habitats such as large or small permanent or temporary ponds and lakes, near ditches, and in bogs or swamps. Twenty-six species (48%) are entirely lentic and another nine species are predominantly so, being only occasionally associated with streams. Thus, 35 of the 55 *Chrysops* species adequately described (65%) may be designated as lentic-inhabiting species.

Six *Chrysops* species (11%) occupy entirely lotic habitats and another four species are found predominantly in lotic habitats, totalling 10 of 55 species (18%) that can be designated lotic-inhabiting species.

Seven species (13%) occupy both lentic and lotic habitats with about equal frequency and apparently are adaptable to a wide variety of habitat types.

The predominance of species preferring lentic habitats occurs in all geographic areas of North America. In eastern North America, 20 species occupy lentic habitats, ten occur in lotic habitats, and four species are found in both. In western North America (west of the 100th meridian), eight species are lentic, two lotic, and one occupies mixed habitats. Of those species occurring in northern areas, occupying an east-west arc across the northern United States and throughout Canada, seven occupy lentic habitats and two occur in both lentic and lotic environments.

Lentic Habitats

Chrysops aestuans van der Wulp.—Banks of a temporary pond; muck soil at waterline of permanent pond (Philip, 1931). Lake shores bordering large lakes (Teskey, 1969).

Chrysops atlanticus Pechuman.—Salt marshes (Teskey, 1969). Shallow water area of a brackish pool 300 yds. from the Atlantic Coast (Goodwin, 1972).

Chrysops calvus Pechuman and Teskey.—Clay soil in the banks of a pool (Teskey, 1969).

Chrysops celatus Pechuman.—Wet sand bordering a small stagnant pond (Teskey, 1969). Margin of a lake in slash pine forest (Tidwell, 1973).

Chrysops clavicornis Brennan.—Wet soil bordering a permanent pond with a dense stand of bulrush, *Scirpus acutus* Muhl. and permanent seepage areas (Lane, 1975).

Chrysops coloradensis Bigot.—Margins of permanent ponds covered with moss and *Eleocharis macrostachya* Britton (Lane, 1975).

Chrysops cursim Whitney.—Wet, grassy margin of a pond in a pineland pasture (Jones and Anthony, 1964).

Chrysops delicatulus Osten Sacken.—Cedar swamp and a long abandoned cranberry bog (Teskey, 1969).

Chrysops discalis Williston.—Shores of lakes and ponds in mud with or without vegetation (Gjullen and Mote, 1945).

Chrysops divisus Walker.—Mud along grassy margins of lakes (Jones and Anthony, 1964).

Chrysops frigidus Osten Sacken.—Swamps, saturated moss on stumps, rocks or windfall in woodland swamps (Teskey, 1969). Moist, sandy silt at margin of a beaver pond and in sphagnum moss in a large swampy meadow (see Results).

Chrysops fuliginosus Wiedemann.—Soil in salt marshes (Teskey, 1969).

Chrysops furcatus Walker.—Swamps; wet moss banks (Teskey, 1969).

Chrysops hinei Daecke.—Grassy margin of a roadside ditch (Jones and Anthony, 1964).

Chrysops hirsuticallus Philip.—Margin and bottom of a temporary pond with *Eleocharis, Eryngium,* and *Juncus* (Lane, 1975).

Chrysops mitis Osten Sacken.—Sloughs (Cameron, 1926). Shore of a lake in deposited sawdust (Philip, 1931). Saturated moss, silt and decaying vegetation of old beaver ponds, woodland pools, alder swamps, and small cattail marshes bordering rivers (Teskey, 1969). Loose sandy silt, loam or gravel at margins of large and small ponds, and the banks of a sluggish drainage canal (see Results).

Chrysops nigripes Zetterstedt.—Saturated moss growing on the banks of pools and wet boggy tundra meadows (Teskey, 1969).

Chrysops parvulus Daecke.—In moss bordering a cranberry bog drainage channel and on the banks of a pool in a cedar swamp (Teskey, 1969).

Chrysops pudicus Osten Sacken.—Wet soil at grassy margin of a roadside ditch (Jones and Anthony, 1964).

Chrysops reicherti Fairchild.—Margin of a farm pond (Hays and Tidwell, 1967). Upper 2 inches of wet mud and organic debris at the margin of a lake (Goodwin, 1972). Small ponds in mixed bottomland hardwood forest and the margin of a small lake in a cypress swamp (Tidwell, 1973).

Chrysops sackeni Hine.—Margins of temporary ponds (Philip, 1931). Wet, grassy sod bordering small pasture ponds, wet leaf mold covering gravelly soil at edge of woodland pool, saturated duff cover on the cattail-overgrown margin of a stream, soft, oozy mud in an alder swamp, and saturated muck soil in a water-filled depression created by an uprooted tree (Teskey, 1969).

Chrysops sequax Williston.—Soft, slimy muck soil on margin of a livestock watering pond in dense growth of *Juncus* (Teskey and Burger, 1976).

Chrysops surdus Osten Sacken.—Permanent seepage areas, margin of a permanent pond (Lane, 1975, 1976).

Chrysops venus Philip.—Saturated moss bordering partly shaded forest pools (Teskey, 1969).

Chrysops virgulatus Bellardi.—Wet soil mixed with decaying vegetation on margin of a large artificial lake and a large permanent desert spring (Burger, 1977).

Chrysops vittatus floridanus Johnson.—Highly organic soil at the edges of swamps and among roots of plants in shallow water (Jones and Anthony, 1964).

Lotic Habitats

Chrysops coquilletti Hine.—Damp sand and silt containing detritus and supporting a stand of cattails (*Typha* sp.) along the banks of the Russian River (Lane, 1975, 1976).

Chrysops macquarti Philip.—Highly organic slightly acidic soil in permanent wet margins of sluggish lowland streams and swamps (Jones and Anthony, 1964).

Chrysops moechus Osten Sacken.—Wet mud and underwater of a small artificial lake (?atypical) (Stone, 1930). In silt along margins of streams (Teskey, 1969).

Chrysops pechumani Philip.—In sand and silt along the Russian River (Lane, 1975, 1976).

Chrysops pikei Whitney.—Muddy margin of a stagnant pool (Jones and Bradley, 1923). Leafy substrate mixed with silt on the banks of a creek (Teskey, 1969). Debris in a narrow, sandy-bottom stream draining a mixed pine-hardwood forest (Tidwell, 1973).

Chrysops univittatus Macquart.—Muddy banks of streams; margins of small ponds (?atypical) (Stone, 1930). Soil in a "pasture draw" (Philip, 1931). Organic muck and decomposing vegetation at the edge of a dairy pond (?atypical) (Hays and Tidwell, 1967). Banks of slow flowing streams (275 larvae) and 1 larva each from the muddy shores of a lake and bottom of a drainage ditch (Teskey, 1969). Margins of a small stream draining a longleaf-slash pine area (Tidwell, 1973).

Lentic-Lotic Habitats

Chrysops aberrans Philip.—Wet, sandy soil at the margins of permanent usually woodland pools and sandy shores or high water pools bordering large lakes (Teskey, 1969).

Chrysops ater Macquart.—Mud or silt rich in organic matter bordering flowing water with a scarcity of vegetation (Teskey, 1969). Loose sandy-silt mixed with organic debris on the banks of beaver dams, coarse sand and gravel banks of a small artificial pond, sandy-silt soil of a large artificial pond, and the banks of a stream in an alder swamp (see Results).

Chrysops brimleyi Hine.—Mucky organic material at edges of lakes and rapidly flowing streams with marsh sedges and grasses (Hays and Tidwell, 1967). Moss or sandy soil with much organic material on the banks of streams, margins of a stagnant pond and organic soils of an abandoned cranberry bog (Teskey, 1969).

Chrysops callidus Osten Sacken.—Mud and decayed leaves on margins of ponds in unshaded localities (Stone, 1930). Shore of a golf pond (Philip, 1931). Substrates around the shores of a lake (Hays and Tidwell, 1967). Wet soil at margins of ponds and silty soils of slow-flowing streams (Teskey, 1969).

Chrysops carbonarius Walker.—Mud among dead leaves and sticks along stream and pond margins (Stone, 1930). Sand and gravel banks of swift streams, with little silt present (Teskey, 1969). Muck soil in a large, marshy meadow adjacent to an alder swamp (see Results).

Chrysops cincticornis Walker.—Muddy margins of ponds and sluggish

woodland streams (Stone, 1930). Muck soil among cattails and sedge of a dairy pond (Hays and Tidwell, 1967). Moss, silt, muck, clay, and sandy soils on the margins of stagnant and freshwater ponds or lakes and along slow flowing streams (Teskey, 1969). Margin of a small stream (Tidwell, 1973).

Chrysops cuclux Whitney.—Very wet mud of sluggish streams or margins of artificial ponds (Stone, 1930). Saturated clay, silt or muck soil bordering streams (Teskey, 1969).

Chrysops dimmocki Hine.—Mud along the grassy margins of lakes (Jones and Anthony, 1964). Wet sand on the margin of a small stagnant pond (Teskey, 1969).

Chrysops excitans Walker.—Shores of a lake (Cameron, 1926). Debris along a lake shore and margin of a temporary pond (Philip, 1931). Wet moss, living and dead vegetation at the margins of a marsh lake, bog ponds, semiwoodland swamp pools and several large northern lakes (Teskey, 1969). Sandy banks of a small stream and sand-silt banks of a slowly flowing drainage canal (see Results).

Chrysops facialis Townsend.—Mineral soil, sod, and moss along margins of permanent streams and ponds (Burger, 1977).

Chrysops flavidus Wiedemann.—Bottom of a small brook (Jones and Bradley, 1923). Wet soil along margins of lakes, streams, and brackish water (Jones and Anthony, 1964). Margins of ponds (Hays and Tidwell, 1967). Sandy bank, freshwater pond (Teskey, 1969). Margins of ponds and waterways (Tidwell, 1973).

Chrysops fulvaster Osten Sacken.—Swamps in ravines and banks of small, sluggish streams (Cameron, 1926).

Chrysops geminatus Wiedemann.—Luxuriant moss in spring-fed drainage beds, margins of a bog lake, silty banks of a stream in an alder swamp and loamy soils at the edge of a flood pool (Teskey, 1969).

Chrysops indus Osten Sacken.—Mud at margins of a small pond and backwater (Stone, 1930). Muck along a creek and temporary ponds with partial shade (Philip, 1931). Sand, silt, clay, organic muck soil and moss at margins of marshy lakes, open and woodland ponds, streams, small rivers, drainage ditches, and farm ponds (Teskey, 1969). Sandy loam soil at margins of large and small natural and artificial ponds, including beaver ponds and alder swamps (see Results).

Chrysops lateralis Wiedemann.—Wet muck soils of small woodland meadows, a boggy backwater of a river, and wet, silty-loam soil beside a pool in a river flood channel (Teskey, 1969).

Chrysops montanus Osten Sacken.—Shore of a small pond in coarse sand saturated with water (Stone, 1930). Shore of a lake (Philip, 1931). Muddy banks of a creek (Teskey, 1969).

Chrysops niger Macquart.—Wet mud in unshaded boggy meadow and

banks of a creek (Stone, 1930). Wet silty mud on the banks of small ponds, streams and rivers, sphagnum bogs, lake margins, and swampy spring-fed seepage beds (Teskey, 1969). Margins of a small stream and a small farm pond (Tidwell, 1973). Muck soil adjacent to an alder swamp and stony clay soil at the margin of a large farm pond (see Results).

Chrysops nigribimbo Whitney.—Wet moss on the banks of streams (Teskey, 1969). Lake margin (Tidwell, 1973).

Chrysops obsoletus Wiedemann.—Highly organic mud on margins of freshwater lakes and streams (Jones and Anthony, 1964).

Chrysops pachycerus var. *hungerfordi* Brennan.—Soil mixed with vegetable debris along the margins of lakes, ponds, cienegas, and small streams (Burger, 1977).

Chrysops shermani Hine.—Denuded sand bar in a river (Teskey, 1969). Sandy silt and muck soils on the banks of small beaver ponds and muck soil adjacent to an alder swamp (see Results).

Chrysops striatus Osten Sacken.—Along shoreline of golf ponds (Philip, 1931). Silty margins of a creek (Teskey, 1969).

Chrysops vittatus Wiedemann.—Wet mud at margins of ponds and streams (Stone, 1930). Wet soil of a wooded seepage area (Jones and Anthony, 1964). Organic debris at edge of a lake (Hays and Tidwell, 1967). Widely distributed in most types of wetland habitats, except for sphagnum bogs (Teskey, 1969). Mud along the margin of a ditch and margin of a river (Tidwell, 1973). Wet sandy silt soil on the banks of a small cattail pond and clay banks of a large reservoir (see Results).

Materials and Methods

During May–July 1977–79, *Chrysops* larvae and pupae were collected throughout the western and northern parts of New Hampshire. Collecting began during the second week of May each year when species of late spring *Chrysops* (especially *C. ater*, *C. mitis*, and *C. indus*) congregated above the waterline to pupate.

Soil was sifted by hand with a three-pronged garden fork and soil clumps were subdivided by hand to collect all larvae and pupae present. Soil was sampled from the waterline to 1 m above waterline and 10 cm deep. Larvae and pupae collected were separated by site and transported to the laboratory in large plastic cups containing wet sphagnum moss and soil substrate.

Mature larvae and pupae were held in large glass dishes furnished with damp sphagnum moss and soil from the larval habitat. Emerging adults were collected once a day and females were caged with 10% sucrose pads for ovarian studies. After emergence was completed, unemerged specimens were counted to determine percent mortality of larvae, prepupae, and pupae collected and the rate of parasitism by a pteromalid wasp, *Diglochis occidentalis* (Ashmead).

Results

Approximately 1230 larvae and pupae of ten *Chrysops* species were collected from ten sites, mostly in Coos County, New Hampshire, during 1977–79. One site, the Colebrook Trout Hatchery, yielded 55% (679) of all larvae and pupae collected. Three sites produced about 80% (979) of all specimens collected. Thus, relatively large samples can be collected from a few sites, yielding abundant study material with minimum collecting effort.

Chrysops mitis, *C. ater*, and *C. indus* were the most abundant species collected. These also occurred in the largest number of collecting sites. Since emphasis was on collection of late spring species, later season species such as *Chrysops lateralis* were not actively sought.

Chrysops mitis Osten Sacken (500).—Larvae and pupae of *C. mitis* were collected from seven sites (six lentic, one lotic). Most of them (447) were found at two sites, the Colebrook Trout Hatchery and the Dixville Golf Course ponds. Preferred habitats seem to be large or small ponds containing emergent vegetation, with loose soil occurring above the waterline, and where rooted vegetation along the banks is sparse. Both larvae and pupae occurred up to 1 m above the waterline 1–5 cm deep in the soil. Both of the above sites are artificial ponds, but have existed for at least 20 years and therefore have natural vegetation occurring in the habitat. Larvae also were collected from a small, gravel-banked artificial pond in Pittsburg, in coarse gravel mixed with sand on a 1 × 0.5 m gravel bar above waterline (21), the steep sandy-silt banks of a slowly flowing drainage canal (16), in wet soil excavated by beavers and deposited above waterline on beaver dams in small ponds (3), and in hard-packed silty soil of a large, artificial farm pond (2). Only the drainage canal could be considered a lotic habitat, but since water flow was imperceptible, it was effectively lentic in the collection area.

Chrysops ater Macquart (225).—Larvae and pupae of *C. ater* were collected from six lentic habitats. All but eight of the larvae were collected from a large beaver pond with loose sandy-silt soil mixed with organic debris on the upper face of the dam and a small artificial pond in Pittsburg with coarse sand and gravel banks. This soil had been excavated by beavers and was sparsely colonized by grasses only. Larvae from the Pittsburg pond were in coarse sand and gravel eroded from the road bed adjacent to the pond. The banks were steep and larvae occurred up to 1 m above waterline. In 1979, most larvae occurred in a gravel bar at one end of the pond, with larvae and prepupae concentrated just above the waterline. Other *C. ater* sites were the Colebrook Trout Hatchery pond (3), a small, active beaver pond (2), an alder swamp with large grassy hummocks above waterline (1), and a large, artificial farm pond (1).

Chrysops indus Osten Sacken (124).—*Chrysops indus* larvae and pupae were collected from five lentic habitats. All but 28 specimens were found along the margin of the Colebrook Trout Hatchery pond, in moist silty loam

soil. Larvae and pupae were associated with *C. mitis*, although adults emerged an average of five days later than *mitis*. Twenty larvae and prepupae were found in loose soil excavated by rodents near the waterline of a golf course pond in Dixville. *Chrysops indus* prepupae also were found in a marshy meadow adjacent to an alder swamp, with larvae occurring in water-saturated loamy soil at the base of grassy hummocks projecting above water (5), in coarse sandy-silt soil at the margin of a small pool with emergent cattail vegetation (2), and in the loose sandy loam soil of an abandoned beaver pond (1).

Chrysops shermani Hine (23).—Larvae and pupae occurred in three lentic sites. Four prepupae were collected on June 15, 1979 from the sand-silt banks of a 15 × 30 m abandoned beaver pond with little emergent vegetation. Predominant vegetation at the collecting site was black and white spruce, balsam fir, white birch, and larch. The larval collection site was sparsely covered with short grasses, but did not have a sod covering. The soil was predominantly sand and dark colored silt, with sticks and grass rootlets intermixed. The soil was loose and friable, easily turned with a garden fork. Prepupae and pupae were found 10–20 cm above waterline at 1–3 cm depth. No specimens were found in muck soil near the waterline.

On July 5, 1979, ten prepupae and five pupae were collected at the same site but in muck soil overlain with a thin layer of sandy silt. All specimens were in soil above the waterline.

One larva was collected from a small marshy meadow adjacent to an alder swamp in Colebrook and three larvae were taken from moist silty soil in the dam of a small, active beaver pond in Waterville Valley.

Chrysops excitans Walker (20).—All larvae, prepupae, and pupae, except one, were collected from the banks of a small stream below the Colebrook Trout Hatchery pond or the banks of a slowly-flowing drainage canal. Examination of numerous apparently favorable lentic habitats where *C. excitans* adults are always abundant failed to produce additional specimens. Sixteen *C. excitans* prepupae and pupae were found in the relatively steep banks of the canal that drains a 5 ha lake and provides water for the Balsams Hotel Reservoir in Dixville Notch. Canal depth at the collection site was approximately 1.7–2.5 m. Because of siltation, it is periodically dredged. Silt is deposited on the sparsely vegetated banks. The friable sandy-silt soil and steep moisture gradient provide ideal habitat for deer fly pupation. *Chrysops excitans* larvae occurred about 5–10 cm above the waterline in moist silt-sand soil, 1–5 cm below the soil surface. Prepupae occurred only where the bank was undercut and where stony substrates and densely matted root systems of grasses did not prevent migration of larvae above the waterline. Generally, prepupae tended to occur in groups of two to four individuals, possibly because larvae congregate in areas favorable for pupation.

Chrysops vittatus Wiedemann (13).—All larvae and prepupae were collected from lentic habitats, especially an abandoned beaver pond, associated with larvae of *C. shermani* (see habitat description under *shermani* above). Larvae also were collected from heavy clay soil on the banks of an old reservoir in Durham (2) and in the wet sandy-silt soil of a small cattail pond in Carroll (2). This last record is particularly interesting because it is the first known record of *C. vittatus* occurring in Coos County, north of the higher mountain peaks in the White Mountains.

Chrysops carbonarius Walker (5).—Five prepupae were collected in a small marshy meadow adjacent to an alder swamp. The area abuts Route 147 northeast of Colebrook and has been extensively flooded by beavers damming a small stream. Surrounding vegetation is predominantly spruce-fir and white birch forest. Prepupae occurred in the highest point of saturated muck soil on a small grassy hummock above the waterline. Specimens of *C. carbonarius* were associated with *C. indus* (5), *C. ater* (1), *C. shermani* (1), and *C. niger* (1).

Chrysops niger Macquart (2).—Only two prepupae of *C. niger* were collected, one from the site described above under *carbonarius* and another from wet stony clay on the shore of a 30 × 50 m artificial farm pond. No shoreline vegetation was present at the farm pond site and the substrate seemed unsuitable for *Chrysops* larvae because it was highly compacted and stony. Two prepupae of *C. mitis* and one of *C. ater* were associated with *niger* at the farm pond site.

Chrysops frigidus Osten Sacken (2).—One prepupa of *C. frigidus* was collected from moist sandy silt soil on a beaver dam, associated with large numbers of *C. ater* prepupae and pupae. Another larva was collected in sphagnum moss in a large, swampy meadow, associated with larvae of *Tabanus marginalis* Fabricius.

Chrysops sordidus Osten Sacken (1).—A single larva (male) of *C. sordidus* was collected in moist silt-loam soil with large numbers of *C. mitis* and *C. indus* from the margin of the Colebrook Trout Hatchery pond. The immature stages of this species have not been reared or described previously. Since the specimen was mixed with *indus* and *mitus*, the last larval exuvium and pupal exuvium was not retained. Although *C. sordidus* is one of the commonest early summer species in northern New Hampshire, breeding sites of the immature stages remain virtually unknown. The reared male is only the second known male specimen in collections.

Discussion

The most consistently favorable collecting sites for larvae were permanent natural or artificial ponds. The three most productive sites in this study were a 15 × 10 m artificial pond, a 40 × 50 m abandoned beaver pond with a large dam still present, and a 40 × 70 m trout hatchery pond maintained for

breeding trout. The least favorable collecting sites for *Chrysops* larvae to date have been the numerous streams of northern Coos County, most of which have granite beds and rocky banks apparently unsuitable for *Chrysops* larvae. Small sphagnum bogs also have not yielded any larvae to date, although this habitat has been only slightly explored.

More than half the larvae, prepupae, and pupae collected came from the Colebrook Trout Hatchery pond. This site was formed by damming a small spring-fed stream and has existed in its present location for at least 75 years, according to records of the New Hampshire Fish and Game Department (Howard Nowell, personal communication). The site is located 2 km east of Colebrook. Dominant vegetation at the site is spruce-fir forest. Grass and herbaceous vegetation surround the pond margin during the summer, becoming quite dense by mid-summer. In spring, the pond margin has little vegetation except the accumulation of the previous years grass stems. Emergent aquatic grasses, particularly American mannagrass (*Glyceria grandis* S. Watson), are present on the north and east banks of the pond. High nutrient water empties into the north end of the pond from trout holding tanks where young fingerlings are given a food slurry.

Larvae, prepupae, and pupae of *Chrysops mitis* and *C. indus* were collected from wet loamy soil around the north and east margins of the pond up to 1 m above the waterline. Prepupae and pupae were higher above the waterline and in drier soil than larvae. Possibly, larvae collected were moving to higher, drier sites prior to the prepupation period. The preferred soil for pupation was a fine-grained mineral soil with mixed loam and plant debris. Most specimens were found where the ground gradually sloped away from the waterline and where soil was relatively loose and wet. Larvae and prepupae were not collected in muck soil at or below the waterline. Some larvae occurred in steeper banks up to 25 cm above waterline, especially where soil was loose, but were rarely found in strongly compacted soil or where grass roots made digging difficult.

Larvae were found 3–5 cm below the soil surface. Prior to the prepupal period, larvae probably seek an optimum moisture content along the moisture gradient from water-saturated to dry soil. At the time of pupation, the prepupa moves vertically upward to within 1 cm of the surface, where pupation occurs. Larvae tend to congregate in especially favorable pupation sites and up to 20 larvae, prepupae, and pupae were collected per 150 cm^3 of soil.

The entire bank of the pond up to 50 cm from the waterline and 5 cm deep was sampled for immature stages of *Chrysops* in 1978 and 1979, yielding 372 and 297 specimens respectively in those years.

Adults of *C. mitis* were first observed ovipositing on blades of American mannagrass (*Glyceria grandis*) on 15 June in 1979. Mannagrass occurred from the waterline to 3 m from the shore in the pond. Oviposition occurred

predominantly on plants in at least 5–10 cm deep water. Up to ten egg masses were found per blade, usually on the underside. The egg masses of *C. mitis* were oval-elongate pointed above and rounded below, 6–9 mm long, 3–5 mm wide, and multi-tiered, unlike the long single tiered masses of some other *Chrysops* species. Of the grasses growing in the larval habitat, only mannagrass, with blades 9–13 mm wide, had a surface suitable for *Chrysops* oviposition. Other grasses had blades narrower than the egg masses observed and were not used for oviposition during this study.

Approximately 217 specimens of *Chrysops ater* were collected from a large beaver pond in Woodstock, near Kinsman Notch, and in a small artificial pond in Pittsburg. The beaver pond is approximately 40 × 50 m and in mixed maple-birch and spruce-fir forest. All larvae, prepupae, and pupae from the beaver pond were collected from soil used by beavers to plug the dam.

The dam on the pond side gradually sloped up from the waterline for about 1 m, then steeply up to the top of the dam, about 1.5 m above the water surface. Prepupae and pupae were concentrated in a 10 m long gradually sloping section of the dam. No specimens were collected in the steeply sloped part of the dam. Pupation occurred in moist, loose sandy-loam soil mixed with organic detritus, grass rootlets, sticks, and small pebbles. The soil probably was deposited on the dam by beavers when the area was active.

In 1979, 115 specimens were collected from the dam; all but four were *C. ater*. Seventy percent of the specimens were pupae on the date of collection (16 May); the remainder were prepupae. Specimens were found up to 1 m from the edge of the water and 1–3 cm deep in the soil. No specimens were collected at or below the waterline.

There is no emergent vegetation in the pond through the growing season. Adults of *C. ater* may have deposited eggs on the leaves of trees overhanging the pond. Subsequent collecting at this site in June and July, 1979 failed to produce additional *Chrysops* specimens. Specimens of *Chrysops mitis* (2), *C. indus* (1), and *C. frigidus* (1) were associated with *C. ater* at this site. All the soil on the surface of the dam was examined for larvae and pupae, but specimens were found only in the 10 m section gradually sloping from the water.

Approximately 110 specimens of *C. ater* were collected during a three year period (1977-79) from a small, artificial pond in Pittsburg. Most of the shore line of this pond is hard, compacted clay, but gravel and sand fill from road shoulder construction has spilled over part of the shore adjacent to the main highway, creating favorable habitat for *C. ater* and other species. The pond is 15 × 10 m, 5–7 m deep, unshaded, and fed by a small stream that enters through an inlet pipe from the north and drains out the south end. Cattails grow along the north bank; shrubby willows and alders overhang the south bank.

Specimens of *Chrysops ater* and *C. mitis* were concentrated along the northern and western banks where loose sand and gravel reached the waterline. Prepupae and pupae were found 5–70 cm from the waterline in moist gravel and sand, usually 2–5 cm below the surface. The coarse, well-drained gravel is apparently the only favorable pupation site around the pond, resulting in concentration of larvae in small areas.

In 1979, a narrow bar (1 × 0.5 m) of sand and coarse gravel was deposited in the pond just below the inlet pipe. Over 100 larvae were collected from this small bar 5–10 cm above the waterline at the highest point of the bar, indicating that subtle changes in the available substrates can drastically affect collecting success at a given site. The previous year (1978) only 13 specimens were collected from the entire shoreline.

No *Chrysops* eggs were discovered on the cattails or on the leaves of alders and willows overhanging the pond in May, June, or July. No larvae or pupae were found at this site later in the season.

Our collection data for *Chrysops* species over a three year period suggest that certain habitats consistently produce large numbers of deer flies and can be used to generate specimens for biological studies on the immature stages and adults of common *Chrysops* species. This is particularly true for some early summer species considered to be pests of humans, livestock, and wild mammals in northern New Hampshire (*Chrysops ater, C. mitis, C. indus*). Other common pest species (*Chrysops excitans, C. sordidus*) have been collected less consistently because their preferred larval habitats have not been discovered or they occur in small numbers in a variety of habitats scattered over a large geographic area inaccessible to intensive collecting.

Several factors appear to affect collecting and rearing success in a given year in the habitats described above. Those encountered in this study were: (1) Synchronization of prepupal and pupal stages and adult emergence; (2) yearly variation in pupation and emergence time; (3) amount and quality of lacustrine substrate available for pupation; (4) seasonal succession of different species in the same habitat; and (5) abundance of parasitoids attacking *Chrysops* larvae.

Prepupal and pupal development in early season deer flies was surprisingly synchronous in 1978 and 1979. During the three year study period, date of pupation of *Chrysops mitis* varied only seven days (17–24 May). Therefore, to collect large numbers of prepupae and pupae, collections must be made after larvae have migrated above the waterline prior to prepupation, but before adults emerge, a period of approximately 15–20 days, from mid-May to the first week of June in northern New Hampshire.

Adult emergence data from 1978–79 laboratory studies suggest that there is a definite pattern of emergence in four early season species studied, the earliest being *Chrysops ater*, followed by *C. mitis, C. excitans*, and *C. indus*. *Chrysops ater* adults emerged between 20–30 May, with most adults

appearing during the period 23–27 May. *Chrysops mitis* adults emerged between 20 May–6 June, but most emergence was in the period 23–30 May. *Chrysops excitans* adults emerged between 1–6 June, but since only 11 specimens were reared, this may not reflect the true emergence interval. *Chrysops indus* is the last commonly reared species to emerge, most adults appearing during the period 3–12 June. This sequence occurs within a single collection site as well as between sites, so this pattern would be expected at all sites, with some modification for later emergence at higher altitudes. Successful collecting, therefore, depends on correct timing for collection of prepupae and pupae of early season *Chrysops* species.

Amount of favorable substrate available for pupation was relatively constant at some sites, but quite variable from year to year at others. Loose soil and gravel-sand substrates were easiest to sample and contained the largest number of larvae and pupae. Numbers collected were particularly variable at two sites: the small, artificial pond in Pittsburg and the golf course ponds at Dixville Notch. A total of 40, 13, and 142 *Chrysops* immature stages were collected in 1977, 1978, and 1979, respectively, from the Pittsburg site. Collecting success was governed by compaction of the sand-gravel banks of the pond adjacent to the road. In 1977, one section of bank, apparently recently formed, was loose and provided a favorable moisture gradient for migrating larvae. In 1978, most of the bank was compacted and difficult to dig, possibly preventing larvae from migrating to drier areas for pupation and greatly reducing collecting success. In 1979, a sand-gravel bar was washed into the pond through the inlet pipe, creating an ideal area for *Chrysops* larvae to congregate above the water. Collecting success thus increased more than 10-fold, since most specimens were collected from the bar.

Turfgrass is maintained around the golf course ponds in Dixville, and most ponds have little loose soil around the margins suitable for pupation. Loose soil is deposited where moles have excavated holes near the waterline, providing ideal habitat for *Chrysops* larvae to migrate and pupate. In 1977, about 60 prepupae were collected from animal-deposited soil above the waterline. In 1979, no animal activity occurred adjacent to the ponds sampled and no prepupae or pupae were collected. Thus, transient year-to-year changes in the nature of substrates at some sites may affect collecting success. *Chrysops* may continue to inhabit these sites, but ability to collect them is limited by the difficulty of sampling sod and compacted soil substrates.

There may be a seasonal succession of species occurring in some of the habitats studied or certain habitats may support species that emerge later in the summer, although this was not studied in detail. One site, a small, abandoned beaver pond, yielded no *Chrysops* when sampled on 16 May 1979. During subsequent sampling on 15 June, prepupae and pupae of *Chry-*

sops shermani and *C. vittatus* were collected from a 2 m section of shoreline. The entire bank of the pond was spot sampled but no additional specimens were found. On 5 July, more larvae and prepupae of *C. shermani* and *C. vittatus* were collected from the same site, indicating that cohorts of larvae, possibly from separate egg masses, were maturing at different times during the season.

Parasitoids of *Chrysops* larvae and pupae may affect rearing success once prepupae and pupae are collected for rearing. Teskey (1969) reviewed the parasitoids associated with immature Tabanidae in North America, including *Diglochis occidentalis* (Ashmead). This pteromalid was particularly common in 1979 at the Colebrook Trout Hatchery site, and we suspect that it may be occasionally abundant enough in particular sites to noticeably reduce adult emergence of *Chrysops*, and therefore affect rearing success in the laboratory. Further studies of this parasitoid in our study sites are in progress.

Despite the vagaries of collecting and rearing large numbers of *Chrysops* adults in the laboratory for biological studies, if highly productive breeding sites can be identified and the sequence of prepupation, pupation, and adult emergence of common species determined, quantitites of adult flies for ovarian development studies can be successfully reared and maintained in the laboratory. Since mature larvae appear not to be cannibalistic, many flies can be reared together in containers, in contrast to other Tabanidae that must be reared individually, a very time-consuming process. *Chrysops* species also tend to aggregate in sites favorable for pupation, allowing collection of hundreds of individuals with minimum effort.

We were able to maintain adult flies in cages for up to 11 days in the laboratory with 10% sucrose as the only energy source. Flies were best maintained in a cool room with relatively little light, since strong light increased flying activity and caused flies to beat themselves against the wire screen cages. We believe that adults can be maintained for up to 21 days in cool, dark conditions.

By utilizing the above collection and maintenance methods for *Chrysops* species and by collecting in the field at appropriate times, we believe that quantities of *Chrysops* adults can be reared and maintained in the laboratory and that these heretofore poorly studied haematophagous insects can be used more commonly for biological studies, particularly morphological studies, feeding studies, and analysis of the ovarian development.

One of the major unsolved problems of rearing *Chrysops* larvae is ignorance of their food preferences. Larvae of some species are thought to be predaceous; others will not attack small, soft-bodied animals and may feed on particulate matter in the mud of streams and ponds. Burger (1977) was able to rear half-grown larvae of *Chrysops pachycerus* var. *hungerfordi* and *C. virgulatus* by mixing soil from the larval habitat and macerated house

fly larvae (*Musca domestica* L.) into a small pellet. Until a suitable food material is discovered for *Chrysops* larvae, studies utilizing reared adults will have to rely on collection of mature larvae, prepupae, and pupae during the relatively short period when they are easily accessible in the field. Once a suitable food source is discovered, larvae can be reared from egg masses collected in the field or from caged wild-caught, blood-engorged female flies.

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NOTE

New Records for *Eriotremex* (Hymenoptera: Siricidae) from Southeast Asia and New Guinea

Specimens of *Eriotremex* are not commonly collected. The ten known species are native to Southeast Asia and New Guinea, but one species, *E. formosanus* (Matsumura), was accidentally introduced into the southeastern United States. The following records are from specimens in the Bernice P. Bishop Museum, Honolulu, Hawaii. I thank Gordon Nishida of that Museum for loaning the material.

Eriotremex formosanus (Matsumura).—Described from Taiwan and recorded from Vietnam, Laos, and southeastern United States. LAOS: Vientiane Prov., Phou Kou Khouei, 800 m, 12–13.IV.1965, J. L. Gressitt (3 ♀).

Eriotremex foveopygus Maa.—Recorded from the islands of Negros and Samar in the Philippines. The following are the first records for Mindanao. PHILIPPINES: Misamis Or., Mt. Empagatao, 1050–1200 m, 19–30.IV.1961, W. Torrevillas (1 ♀); Misamis Or., Mt. Balatukan, 15 km SW of Gingoog, 1000–2000 m, 27–30.IV.1960, H. Torrevillas (2 ♀); Misamis Or., Minalwang, 31.III.1961, H. Ton. (1 ♀).

Eriotremex insignis (F. Smith).—Described from Aru Island, Indonesia and also recorded from West Irian, Indonesia and Papua New Guinea. PAPUA NEW GUINEA: NE, Bupu R., Sitium Vill., 19 km NE of Lae, 30+, Forest, 15.IV–15.V.1970, light trap, N. R. Spencer (1 ♀); Fly R., Kiunga, 35 m, VIII.1969, J. and M. Sedlacek (1 ♀).

Eriotremex sp., ♂.—The taxonomy of *Eriotremex* is based on females; very few males have been associated. This unidentified male may represent a described species. It is the first record of the genus from Thailand. THAILAND: NW, Chiangmai: Doi Pui, 1360 m, 2.V.1958, T. C. Maa (1 ♂).

David R. Smith, *Systematic Entomology Laboratory, IIBIII, Agric. Res., Sci. and Educ. Admin., USDA, % U.S. National Museum of Natural History, Washington, D.C. 20560.*